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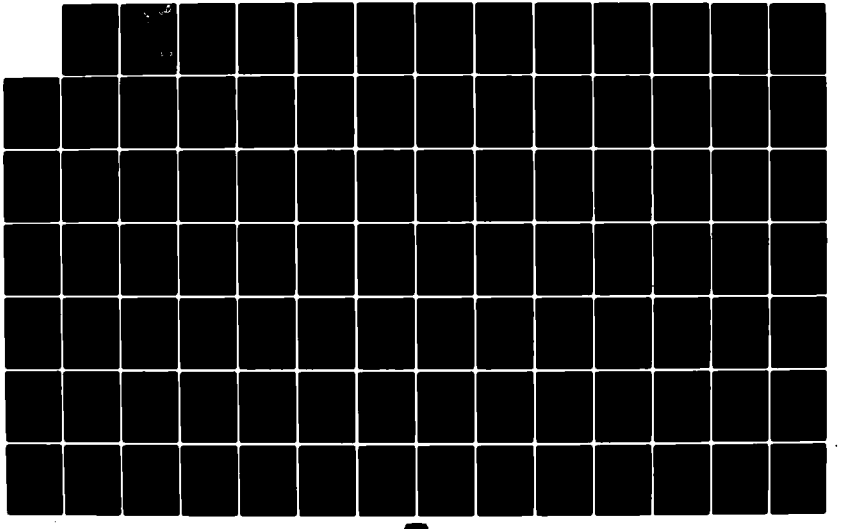

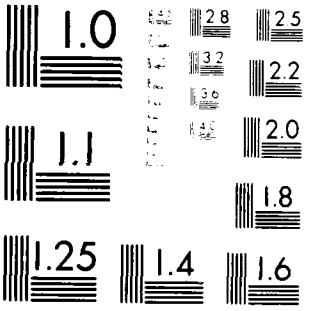

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AN ANALYSIS OF FACTORS AFFECTING THE USE OF CHANGE ORDERS AND SUPPLEMENTAL AGREEMENTS

Kevin P. Grant, First Lieutenant, USAF

LSSR 78-83

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER LSSR 78-83	2. GOVT ACCESSION NO. A134977	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANALYSIS OF FACTORS AFFECTING THE USE OF CHANGE ORDERS AND SUPPLEMENTAL AGREEMENTS		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kevin P. Grant, First Lieutenant, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Systems and Logistics Air Force Institute of Technology, WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Communication AFIT/LSH, WPAFB OH 45433		12. REPORT DATE September 1983 13. NUMBER OF PAGES 95
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release: IAW AFR 190-17.

LYNN E. WOLAVER
Dean for Research and Professional Development
Air Force Institute of Technology (ATC)
Wright-Patterson AFB OH 45433

15 SEP 1983

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Contract Proposals
Configuration Management
Modification
Contract Administration
Contracts

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thesis Chairman: William F. Shaw, Lt Col, USAF

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Program Managers must often decide whether an engineering change proposal should be incorporated by change order, or by supplemental agreement. Currently, they are unable to assess the cost and schedule effects of each alternative at the time of their decision. The objectives of this study were to first quantitatively compare the cost and schedule effects of both methods, and second, to devise and test a model to assist program managers in selecting between each alternative. The data for this study were extracted from change orders and supplemental agreements issued during 1981 against the two major production contracts used to acquire the Fairchild Republic Company A-10A weapon system. This study concludes that there is not a statistically significant (α=.05) difference in the cost effects of either alternative, however, the change order was more expedient than the supplemental agreement. This study also devised a model. Three methods were applied to test the validity of the model: case analysis, correlation analysis, and algebraic analysis. All three tests were inconclusive. Although the study did not validate the model, recommendations for successful application are provided.

LSSR 73-83

AN ANALYSIS OF FACTORS AFFECTING THE USE OF CHANGE ORDERS AND SUPPLEMENTAL AGREEMENTS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

By

Kevin P. Grant, BS
First Lieutenant, USAF

September 1983

This thesis, written by

lLt. Kevin P. Grant

has been accepted by the undersigned on behalf of the Faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS MANAGEMENT

DATE: 28 September 1983

William F. Shane
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READER

ACKNOWLEDGEMENTS

There are several individuals whose assistance contributed significantly to the success of this thesis.

First, I would like to thank Mr. George Kaplan and Ms. Eileen Arroll of the Fairchild Republic Company (FRC), and Ms. Cathy Safarik of the AFPRO at the FRC-Farmingdale plant, who were very helpful in providing data, early in this effort.

Second, I would like to thank Major Jay Freedman for his invaluable assistance when it came time to talk to the computer. Major Freedman transformed a potential nightmare into a simple communication exercise. Thanks again.

Third, I would like to thank my typist, Patricia Kessel, who unselfishly made room for my thesis time and time again. Professionally, typing is always appreciated, but typing all night to meet deadlines is well beyond the call of duty. Thanks, Pat.

Finally, I would like to thank my advisor Lt. Col. William F. Shaw, and my reader, Major Harman T. Withee, who by their attention, and constructive criticism helped transform this thesis from an "undergraduate term paper" into a piece of worthwhile research. Thanks for the time, patience and assistance.

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CHAPTER I

INTRODUCTION

Preface

The DOD acquires major weapon systems through contractual efforts between the government and civilian corporations. As a major weapon system progresses through the acquisition life cycle and enters the production and deployment phase, design deficiencies will surface which require correction. The correction of these deficiencies is generally accomplished through the implementation of an engineering change proposal (ECP) which has been approved by the configuration control board of the responsible system program office. The implementation of an ECP requires modification of the contract because the change contains "terms [which are] different from those which were agreed upon in the original contract [4:87]." There are two contractual tools available to modify the contract under the authority of the change clause; these are the unilateral change order and the bilateral supplemental agreement.

Literature Review

Topic

This literature review addresses factors to consider in the use of the change order and the supplemental agreement.

This review emphasizes the cost and schedule characteristics of each method.

Key Terms

1. Advanced Change Study Notice (ACSN) -- A document (AFSC Form 223) which precedes a preliminary or formal ECP (or contract change proposal) and which contains information establishing the need for the change. It is used to allow effective initial evaluation of the suggested change [13:84].

2. Ceiling Price -- This is the dollar amount at which the government obligation ceases. When contract cost reaches this point, the contractor's profit is zero dollars. Any expenditure beyond the ceiling price must be absorbed by the contractor from sources not obligated on the instant contract under consideration [10:133]. The term ceiling price is peculiar to fixed price incentive contracts [9].

3. Change Order (C/O) -- A written order signed by the contracting officer, directing the contractor to make changes which the changes clause of the contract authorizes the contracting officer to order without the consent of the contractor (often referred to as "unpriced actions") [12:1:15].

4. Configuration Control Board (CCB) -- A board composed of representatives from program/project functional areas such as engineering, configuration management, procurement, production, test and logistics support, training activities and using/supporting organizations. This board approves or disapproves proposed change requests with each member recording his organization's official position [on the ECP]. The program/project manager is normally the board chairman and makes the final decision on all changes [13:85].

5. Contract Modification -- Any written alteration in the specification(s), delivery point, rate of delivery, contract period, price, quantity, or other contract provisions of an existing contract, whether accomplished by unilateral action

in accordance with a contract provision, or by mutual action of the parties to the contract. It includes (i) bilateral actions such a. supplemental agreements, and (ii) unilateral actions such as change orders, orders for provisioned items, administrative changes, notices of termination, and notices of the exercise of a contract option [12:1:15].

6. Definitization -- The process by which the government and the contractor agree to the specific tasks to be performed under the scope of a contract modification and determine the negotiated price associated with those tasks [9].

7. Engineering Change Proposal (ECP) -- A formal, priced document (DD Forms 1692) used to propose changes to the contract provisions and scope... especially when related equipment, (configuration items), interfaces or technical manuals are affected or retrofit is involved [13:86].

8. Not-to-exceed (NTE) price -- A not-to-exceed price serves the same purpose for change orders that a ceiling price does for fixed price incentive contracts. Specifically, the NTE price caps the goverment's liability if the contractor is performing an unpriced effort. Any expenditure beyond the NTE price must be absorbed by the contractor [9].

9. Price Adjustment Factor -- A term used exclusively in this thesis effort, the price adjustment factor is the difference between the not-to-exceed price submitted with an unpriced proposal and the final definitized price of the ECP expressed as a percentage of the original NTE.

10. Production Effectivity -- The sequential number associated with the first system to receive a modification in production.

11. Program Manager (PM) -- The single Air Force Manager (system program director, program or project manager, or system or item manager) during any specific phase of the acquisition life cycle [14:96].

12. Supplemental Agreement -- Any contract modification which is accomplished by the mutual action of the parties [12:1:18].

Discussion

The literature reviewed for this research effort included many periodicals, government publications, regulations, and Department of Defense sponsored research reports. The information reported in this discussion has been extracted from Department of Defense sponsored research projects which address contract modifications.

The literature reviewed in this study discussed six factors to consider when incorporating an ECP by change order. The first factor, reported by McMaster in A Procurement Guide for Special Projects Officers is a loss of cost control when a modification is incorporated by change order. McMaster explains this characteristic of the change order as follows:

> Urgent changes in the requirements can be incorporated by a change order prior to price negotiation provided a ceiling price for the changes has been received by the contracting officer from the contractor. This ceiling price is usually prepared in haste by the contractor, and, therefore,

> is usually pessimistic in order to cover estimating errors. Nevertheless, when the change is incorporated, funds in the full amount of the ceiling price must also be obligated on the contract. From that time until the price of the change is determined, through negotiation of a supplemental agreement, the contract ostensibly contains more funds than are required for the tasks and the contractor is effectively without an incentive to control costs [6:55-56].

In a study of change order administration within the Army Materiel Command (AMC), Williams and Beeckler report a second factor to consider in the use of the change order. This factor also stems from the practice of obligating excess funds in the full amount of a pessimistic ceiling price when the change order is issued. Williams and Beeckler found that the use of a change order can unnecessarily prevent the program manager from implementing additional programs which are competing for the funds obligated by the change order [15:17].

A third factor to consider in the use of a change order is a possible loss of negotiating leverage. In an effort to retain cost control and recover the use of obligated funds the DAR prescribes "that price adjustments resulting from unpriced changes. . . shall be negotiated in the shortest practicable time [6:56]." Williams and Beeckler point out, however, that there is an adverse result associated with the requirement for timely definitization of change orders. Namely, that in an effort to promptly negotiate an equitable adjustment the negotiator may make expedient concessions which favor the contractor [15:26].

A fourth factor to consider in the use of the change order is the possibility that the contractor may use the change order to "get well." This factor is discussed in McMaster's guide as well as J.D. Graham's report, Change Orders - Some Control and Pricing Aspects. In both sources the authors display concern over the likelihood that contractors may use the change order to reap a business or profit "windfall," or to "get well" when the basic contract is in financial trouble due to mismanagement [2:4, 6:56].

Several sources identified timeliness as a fifth factor to consider when using the change order. Martin et al reported that in a survey administered to approximately 300 experienced DoD procurement personnel representing all DoD procurement agencies "all [agencies] responded that the unilateral change order issued pursuant to the changes clause was the most timely (contract modification instrument)" [5:24:110]. Williams and Beeckler similarly reported in their study Change Order Administration that:

> There are occasions when quick implementation of the change is necessary in order to eliminate a bottleneck or solve an engineering problem. Time may not permit the negotiation of a bilateral agreement. In such situations the changes clause gives the contracting officer the right to make a change by means of a written change order [15:6].

McMaster also discussed the timeliness of the change order in his report A Procurement Guide for Special Projects Officers where he stated that in the case of special projects:

> The need to incorporate the revisions becomes urgent lest the program schedule be delayed. Urgent changes in the requirements can be incorporated by a change order prior to price negotiations provided a ceiling price for the changes has been received by the contracting officer from the contractor [6:55].

Martin et al discuss a sixth factor which should be considered when using a change order. This factor is the timing of the change. Martin et al assert that:

> Uncontrolled changes often lead to different product configurations that seriously complicate the operation and support of the equipment in the field. Poorly timed changes may disrupt contractor operations unnecessarily, create scrap or rework, and generally increase cost to the government [5:3].

With respect to the supplemental agreement, the literature discussed five factors to consider in the use of a supplemental agreement. The first three were generated by a survey administered to 300 procurement personnel. Martin et al report that survey respondents from all agencies ranked the supplemental agreement as the most:

1. flexible
2. manageable, and
3. cost effective

contract modification instrument [5:108].

The fourth factor to consider in the use of the supplemental agreement is DoD procurement policy. The Defense Acquisition Regulation (DAR) requires the use of the supplemental agreement "in preference to a change order when a supplemental agreement is considered feasible, even though

authority exists to accomplish the modification by change order [12:26:7]. Williams and Beeckler explain the preference for the supplemental agreement by observing that with the supplemental agreement the government and the contractor can agree to terms "regarding the extent of the change, the price of the change, and any required adjustment to the delivery schedule" [15:6] before granting authorization to proceed.

A fifth factor to consider in the use of a supplemental agreement is the impact of the delayed "start date" which is associated with the supplemental agreement [5:110]. In a report to the Congress entitled Opportunity to Reduce Costs and Improve Aircraft Through Prompt Processing of Engineering Change Proposals the Comptroller General of the United States reported that:

> Usually, some aircraft are in production while the proposed engineering change is being evaluated. Delays in processing the change proposal can increase the number of unchanged aircraft completed and delivered to the operating forces. Once those aircraft are delivered to the users, the change could be delayed for months or years or never be made at all. Moreover, making such changes after production is generally more expensive [11:1].

McMaster takes a similar position.

> In case of added requirements, the price of the modification is the result of the cost of work added plus the cost of reaccomplishing previously performed work -- work made useless -- in order to integrate the new requirement into the system. For a given added requirement the magnitude of the work made useless

> will increase with contract age. The cost of the work made useless constitutes an undesirable cost growth since it represents lost return of government investment [5:57].

Finally, an underlying disadvantage of the delayed "start date" offered by Martin et al is that it increases the time that the users must live with the deficiency, indeed "delayed changes. . . may jeopardize corrective actions designed to avoid fatal or serious injury to operating personnel [2:3].

Summary

This literature review has identified many factors which should be considered when deciding between the change order and the supplemental agreement. The literature has revealed that with the change order there is a loss of cost control [6:56]. Secondly, the use of the change order obligates funds which cannot be used elsewhere until the change is definitized [15:17]. A third factor to consider is that the requirement for the timely definitization of change orders can undermine the negotiator's leverage and result in concessions which favor the contractor [15:26]. Additionally, there is always the possibility that the contractors are using the change order to compensate for their "buy in" prices or mismanagement [2:4, 6:56]. Despite these limitations the change order is the most expedient way to incorporate a change [4:10]. Finally, the change order requires careful planning to insure the changes are controlled and do not result in differing configurations or excess scrap or

rework [5:3].

For the supplemental agreement, the literature indicated that it is more flexible, manageable and cost effective than the change order [5:108]. Furthermore, the DAR prescribes the use of the supplemental agreement whenever practicable [12:26:7]; however, the decision to use a supplemental agreement must consider the associated time delay which can result in a delay in production effectivity, potentially greater retrofit costs, and periods of hazardous operational use [11:1, 6:57, 5:31].

In conclusion, the literature shows that authorizing the contractor to proceed prior to definitization of the effort as with change orders results in a higher cost because the contractor is essentially working on a cost plus basis and therefore has less incentive to control costs. On the otherhand, the literature has indicated that waiting to definitize the effort prior to authorizing the contractor to proceed as with supplemental agreements results in a more costly retrofit effort. A reasonable rule for determining which method should be used to modify the contract where safety factors do not overrule in favor of the change order is to estimate the cost for both alternatives and use the least expensive one [8:7].

Problem

Program Managers must frequently decide whether to

incorporate a given ECP into an existing contract by change order or supplemental agreement. These managers are fully aware of the policy which favors the supplemental agreement. There has been only limited quantitative research comparing the cost and schedule effects of the change order and the supplemental agreement. Hence it is useful to investigate quantitatively, the cost and schedule effects of these two modification methods.

Research Objectives

There are two objectives of this project. The first is to quantitatively compare the cost and schedule effects of the change order and the supplemental agreement. The second is to devise and test a model to assist program managers in determining whether an ECP should be incorporated by a change order or a supplemental agreement.

Research Questions

1. How does the price adjustment factor for change orders compare to the price adjustment factor for supplemental agreements in those instances where the program office has received an unpriced proposal and can select either method of contractual incorporation?

2. How does the time required to incorporate a change order compare to the time required to incorporate a supplemental agreement in those instances where the program office has received an unpriced proposal and can select

either method of contractual incorporation?

3. For those situations where the contractor submits an unpriced ECP, will the proposed model help program managers predict which method of contractual incorporation will result in the lowest negotiated price?

Scope

This research effort will analyze the cost and schedule effect of unilateral change orders and bilateral supplemental agreements which are subject to the changes clause. The contract modifications studies will be restricted to those which are generated by engineering change proposals.

Specifically, this study will focus on all change orders and supplemental agreements issued against the two major production contracts used to acquire the Fairchild Republic Company A-10A weapon system during 1981.

CHAPTER II

METHODOLOGY

Introduction

This study was conducted in two phases. Phase I determined the cost and schedule characteristics of the change order and supplemental agreement. During Phase II the cost and schedule characteristics of the change order and supplemental agreement determined in Phase I along with information provided in the ECP were used to test a quantitative model designed to predict the least costly method of modifying the contract.

Population

The data population for this study consists of all change orders and supplemental agreements issued pursuant to the changes clause which incorporated an ECP into an A-10 weapon system contract.

Sample

The study sample space will include only contract modifications issued against contracts F33657-78-C-0135 and F33657-79-C-0502 during calendar year 1981. These major production contracts with the Fairchild Republic Company were used to acquire the A-10A Thunderbolt II close air support

aircraft. Additionally, this study was limited to cases where the ECP was submitted as an unpriced effort with a not-to-exceed price.

Phase I

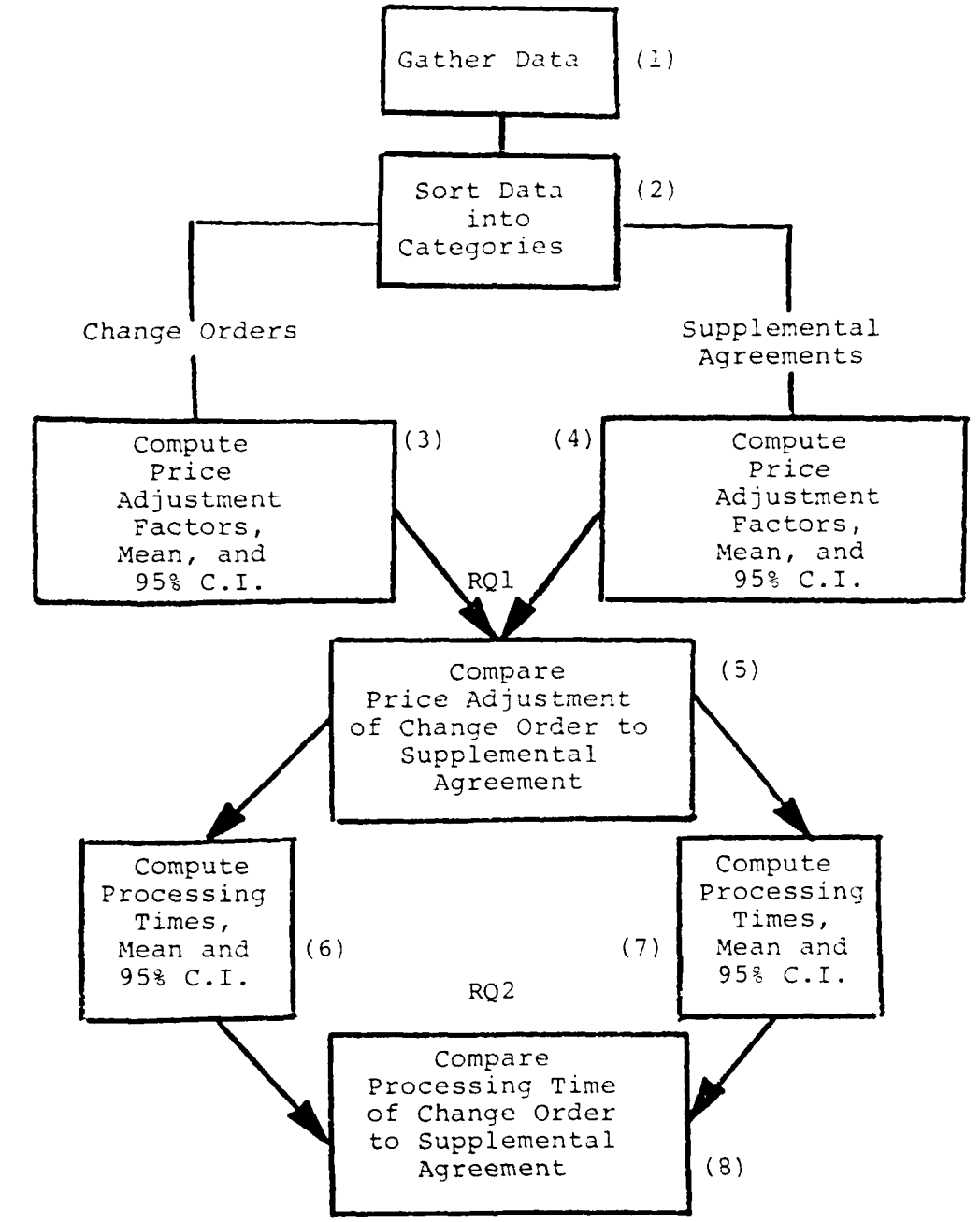
Purpose

The first phase of this research effort determined the cost and schedule characteristics of the change order and supplemental agreement. Successful completion of Phase I answers research questions one and two. The steps required to complete Phase I are illustrated in Figure 1 "Phase I - Procedures."

Procedures

Step 1: Gather data. The first step in completing Phase I was to identify the discrete sample points which were used in this research effort. The sample points for this study were extracted from the contract modification log books for contracts F33657-78-C-0135 and F33657-79-C-0502 which are located in the Tactical Systems Contracting Office in Aeronautical Systems Division. Once the appropriate contract modifications had been identified, the raw data required to perform both Phase I and Phase II was extracted from the appropriate contract files and ECP folders. The contract files and the ECPs are also located in Aeronautical Systems Division.

Step 2: Sort data into categories. Once the data



(#) corresponds to
step number in text

Fig. 1. Phase I - Procedures

was collected, it was sorted into two categories: change orders and supplemental agreements. The contract modification form (Applicable AFSC Form 702, block 14) was used to distinguish between change orders and supplemental agreements.

Step 3: Compute price adjustment factors, mean and 95% confidence interval for change orders.

The price adjustment factor for change orders (PAF_C) was calculated as follows:

$$PAF_C = \frac{P_S - P_f}{P_S} \qquad (1)$$

where:

P_S is the ceiling price (in dollars) associated with an unpriced ECP. P_S is always a not-to-exceed price in ECPs submitted against the contracts used in this study.

P_f is the definitized price (in dollars) of an ECP as negotiated in a bilateral supplemental agreement. ECPs incorporated by change order are definitized by a supplemental agreement.

Once PAF_C was determined for each change order, a mean and 95% confidence interval were established.

Step 4: Compute price adjustment factors, mean, and 95% confidence interval for supplemental agreements.

The price adjustment factors for supplemental agreements (PAF_s) were calculated in the same manner as PAF_c. Once PAF_s was determined for each supplemental agreement, a mean and 95% confidence interval were established.

Step 5: Compare price adjustments of change order to supplemental agreements.

Completion of Step 5 answered research question 1. Essentially, this step involved comparing the statistics determined in Step 3 for change orders to those determined in Step 4 for supplemental agreements.

Step 6: Compute processing times, mean, and 95% confidence interval for change orders.

The processing times were calculated as follows:

$$T_c = T_f - T_b \qquad (2)$$

where:

T_c is the number of days between the date the program office receives an ECP and the date the contractor is authorized by change order to proceed with the effort.

T_f is an integer value which corresponds to the effective date of the contract modification which authorizes the contractor to begin work.

T_b is an integer value which corresponds to the

date the program office receives the ECP.

Once T_c was determined for each change order a mean and 95% confidence interval were determined.

Step 7: Compute processing times, mean and 95% confidence intervals for supplemental agreements.

T_s is the number of days between the date the program office receives an ECP and the effective date of the supplemental agreement which authorized the contractor to proceed with the effort. The processing time for supplemental agreements (T_s) were calculated in the same manner as T_c. Once T_s was determined for each supplemental agreement the mean and 95% confidence interval were determined.

Step 8: Compare the processing time of change orders to supplemental agreements.

This final step compared the statistics determined in Step 6 for change orders with those determined for supplemental agreements in Step 7. Completion of Step 8 answered research question 2.

General Formulas

The means calculated in Steps 3, 4, 6, and 7 were calculated as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (3)$$

where:

$\bar{x}$ = sample mean

n = the number of observations

x_i = the i-th observation

The confidence intervals calculated in Steps 3, 4, 6, and 7 were calculated as follows [3:325]:

$$\bar{x} - t_{(\alpha/2,\nu)} \frac{S}{\sqrt{n}} \leq \mu \leq \bar{x} + t_{(\alpha/2,\nu)} \frac{S}{\sqrt{n}} \qquad (4)$$

where:

$\bar{x}$ = sample mean

t = constant associated with a level of significance and the degrees of freedom for a distribution which is assumed normal

α = 1 - the desired confidence interval
1 - .95 = .05, in this case, ($\alpha/2$ = .025)

ν = degrees of freedom (n-1)

S = standard deviation of the sample

n = the total number of observations

μ = the population mean

This formula is used when the population is assumed normal, and the standard deviation for the population is unknown.

Hypothesis tests were conducted to complete Steps 5 and 8. These tests were performed using the following procedures [3:378-379].

Test on the difference between two means (σ_1^2 and σ_2^2 unknown but assumed equal).

1. Formulate null hypothesis.

   H_o: $\mu_1 - \mu_2 \geq 0$

2. Formulate alternate hypothesis.

   H_a: $\mu_1 - \mu_2 < 0$

3. Establish desired level of significance and corresponding critical region.

   α : .05

4. Compute the test statistic.

$$t_{(n_1 + n_2 - 2)} = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1 + n_2 - 2} \quad \frac{n_1+n_2}{n_1 x n_2}}} \qquad (5)$$

All of the variables used in equation 5 were defined following equation 4, with two exceptions:

σ^2 = population variance

S^2 = sample variance

5. Compare the test statistic to the critical region and draw conclusions regarding hypothesis. If the test statistic falls in the critical region the null hypothesis can be rejected.

After all eight steps of Phase I were completed, re-

gression analysis was used to determine if there was a correlation between the price adjustment factor obtained for any given ECP and the time required to process that ECP. As a starting point, it must be understood that regression describes the nature of a relationship between variables. Correlation describes the strength of this relationship [15: 526]. When a regression is performed it generates a sample correlation coefficient, r. This coefficient is also known as the Pearson correlation coefficient [16:33]. The Pearson correlation coefficient can take on any value between -1 and +1. A value near +1 indicates a very strong positive correlation, whereas a value near -1 indicates a very strong negative correlation. Values near zero indicate very weak correlations.

Each time regression was performed in this study, the sample correlation coefficient (r) was tested for statistical significance as follows [3:528]:

1. Formulate null hypothesis.

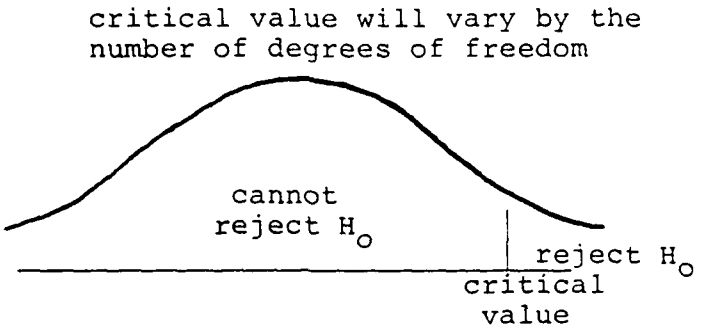
   H_o: $p = 0$ (no correlation)

2. Formulate alternate hypothesis.

   H_a: $p > 0$ (there is a correlation)

3. Determine desired level of significance and corresponding critical region.

α : .05



4. Compute test statistic.

$$t_{(n-2)} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \qquad (6)$$

5. Determine conclusion. If the test statistic is greater than the critical value the null hypothesis can be rejected, otherwise it cannot be rejected.

Phase II

Purpose

The purpose of Phase II was to test a model to determine its usefulness in assisting program managers in deciding whether to incorporate an ECP by change order, or by supplemental agreement. The model applies to those cases where the contractor has submitted an unpriced ECP with a not-to-exceed price. The model procedures are illustrated in Figure 2 - "Phase II - Procedures."

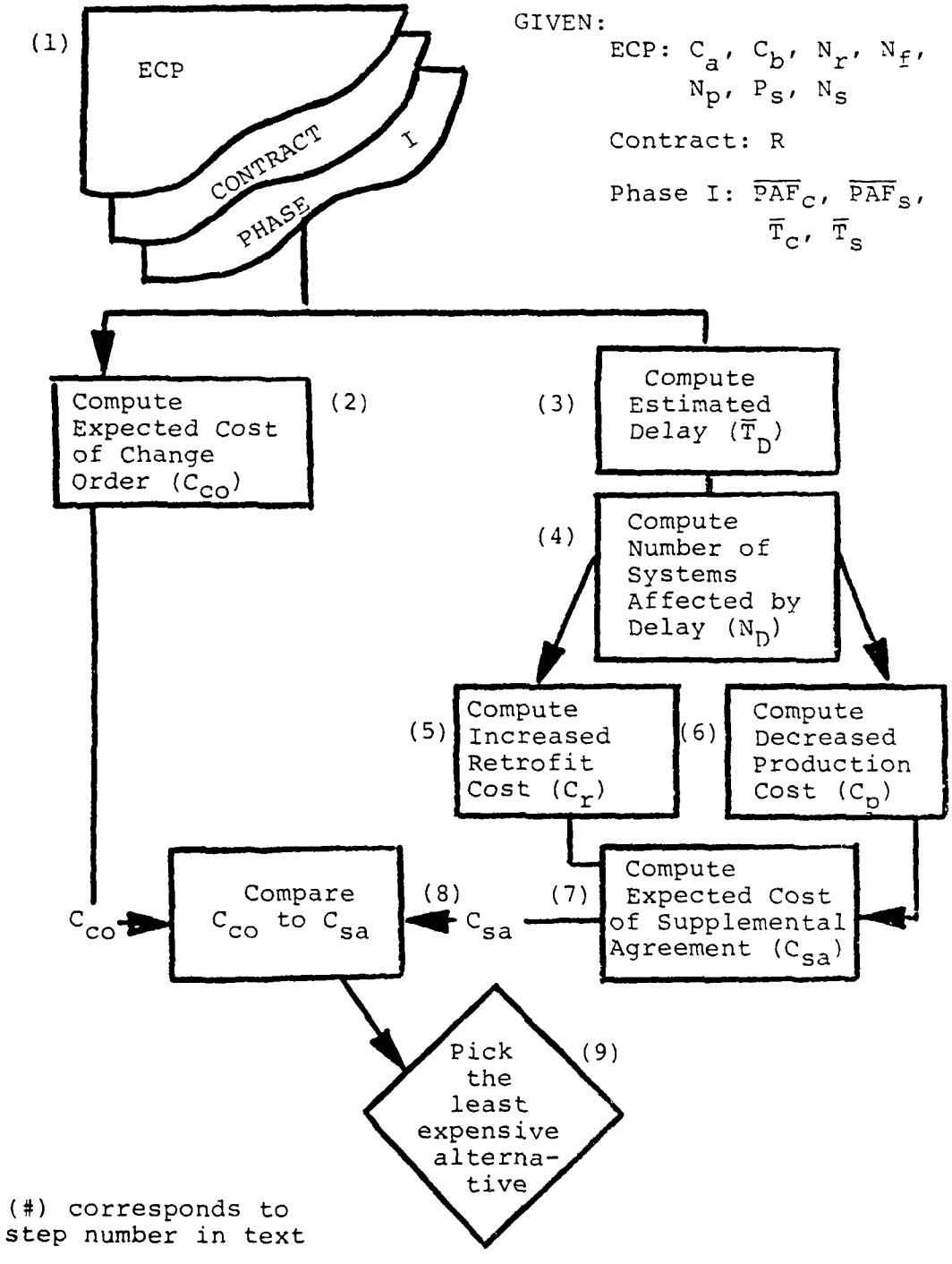


Fig. 2. Phase II - Procedures

Model Procedures

Step 1: The first step of the model was to collect the information required to apply the model. The following information was extracted from the ECP:

C_a is the total recurring retrofit costs of an ECP (dollars) -- DD Form 1692-3, Block 48 b (4).

C_b is the total recurring production costs of an ECP (dollars) -- DD Form 1692-3, Block 48 a. (4).

N_r is the number of systems requiring retrofit in and ECP (systems) -- DD Form 1692, Block 20 a.

N_f is the sequence number of the last system to be produced under the existing contract (usually presented in an attachment, also available in the contract).

N_p is the sequence number of the first system to received the change while in production. This value is also known as the production effectivity -- DD Form 1692, Block 18.

P_s is the ceiling price (or NTE) of the unpriced ECP (dollars) -- DD Form 1692-3, Block 48 (6).

N_s is the number of systems receiving the modification during production for each contract (usually presented in an attachment and can be calculated using N_f and N_p).

The following information was extracted from the contract:

R is the monthly production rate of a system (systems/month).

Finally, Phase I generated the following information:

$\overline{PAF}_c$ is the mean price adjustment factor for change orders.

$\overline{PAF}_s$ is the mean price adjustment factor for supplemental agreements.

$\bar{T}_c$ is the mean processing time for change orders (days).

$\bar{T}_s$ is the mean processing time for supplemental agreements (days).

Step 2: Compute the expected cost if incorporated via change order (C_{co}).

$$C_{co} = P_s(1 - PAF_c) \tag{7}$$

Step 3: Compute the estimated time delay ($\bar{T}_D$).

$$\bar{T}_D = \bar{T}_s - \bar{T}_c \tag{8}$$

Step 4: Compute the number of systems affected by the delay (N_D).

$$(\frac{T_D}{30})(R) = N_D \quad (9)$$

Step 5: Compute increased retrofit cost (C_r). First compute recurring retrofit cost per unit (C_u).

$$\frac{C_a}{N_r} = C_u \quad (10)$$

Now the increased retrofit cost can be calculated.

$$C_r = (N_D)(C_u) \quad (11)$$

Step 6: Compute decreased production cost (C_p). First compute recurring production cost per unit (C_v).

$$\frac{C_b}{N_s} = C_v \quad (12)$$

Now the decreased production cost can be calculated.

$$C_p = (N_D)(C_v) \quad (13)$$

Step 7: Compute expected cost of supplemental agreement (C_{sa}). First compute expected revised price of the fully priced proposal (P_p).

$$P_p = P_s + C_r - C_p \quad (14)$$

Now the expected cost if incorporated via supplemental agreement can be calculated.

$$C_{sa} = P_p(1 - \overline{PAF}_s) \quad (15)$$

Step 8: Compare C_{co} to C_{sa}.

Compare the estimated cost to incorporate the ECP via change order (C_{co} from Step 2) to the estimated cost to incorporate the ECP via supplemental agreement.

Step 9: Select the least expensive alternative, unless overriding issues require the use of a change order.

Test of Model

The validity of a model is a measure of the extent to which the model predicts what actually occurs. This study employed three methods of testing the validity of this model. The first method was case analysis. With this method the model was applied to two specific cases and the estimated results were compared to the actual results. The second method was correlation analysis where Pearson correlation coefficients were calculated to determine if there was a significant correlation between estimated and actual results for all sample points, change orders only and supplemental agreements only. Finally, algebraic analysis was applied to test the validity of the model. Once the model

was reduced to its fundamental arithmetic relationships, inferences were drawn concerning the validity of the model.

Sensitivity Analysis

After the validity of the model was tested, sensitivity analysis was performed in an effort to improve the model. Regression analysis was performed to determine if their was a linear relationship between the original not-to-exceed price and the price adjustment factor. Regression analysis was also conducted to ascertain if their was a linear relationship between the original not-to-exceed price and the processing time for each effort. In cases where the regression analysis indicated a linear relationship the model was refined to include that relationship. The correlation coefficients were tested for statistical significance with the procedures discussed earlier in this chapter (ref. Equation 6).

Finally, an analysis of variance (ANOVA) was performed to determine if the price adjustment factors varied as a function of time. All regressions, correlation coefficients, and the ANOVA were calculated through the use of the Statistical Package for the Social Sciences (SPSS9).

CHAPTER III

FINDINGS AND ANALYSIS

Introduction

The purpose of Chapter III is to present the findings of this study and apply those findings to the acquisition environment. The chapter will first present the findings of Phase I. The analysis of these results will answer research questions 1 and 2. The next section, titled "Phase II," will include two case analyses, correlation analysis, algebraic analysis, sensitivity analysis and model refinement. The analysis in Phase II will answer research question 3. The application section will then discuss the use of the findings from Phase I and Phase II in the acquisition environment. The main points of the chapter will be summarized in the final section.

Phase I

Data

The data search for this study identified 51 potential data points within the sample space. These data points are displayed in Appendix A "Sample Points." The 51 potential data points were then sorted into two categories:

1. Change Orders (Appendix B "Change Orders").
2. Supplemental Agreements which incorporated ECPs

submitted originally as an unpriced proposal (Appendix C "Supplemental Agreements").

Originally, each supplemental agreement presented in Appendix C "Supplemental Agreements" would have served as an independent sample point. As the data were collected, however, it became apparent that the only way to compare a not-to-exceed price to a final definitized price which addressed the same number of aircraft was to group the contract modifications which incorporate the same ECP. This grouping method will adjust for the shifting effectivity which accompanies a delay in contractual incorporation.

Research Question 1

How does the price adjustment factor for change orders compare to the price adjustment factor for supplemental agreements in those instances where the program office has received an unpriced proposal and can select either method of contractual incorporation? The mean price adjustment factor for change orders ($\overline{PAF}_C$) was 29.432%. This means that the initial not-to-exceed price for change orders was reduced by an average 29.432% as a result of the definitization process. The 95% confidence interval for the price adjustment factor for change orders is as follows:

$$23.01 \leqslant \mu \leqslant 35.85$$

This confidence interval indicates that $\overline{PAF}_c$ will fall between 23.01 and 35.85% 95 percent of the time.

The mean price adjustment factor for supplemental agreements ($\overline{PAF}_s$) was computed to be 23.387%, indicating that for supplemental agreements the initial not-to-exceed price was reduced an average of 23.387% as a result of the definitization process. The 95% confidence interval for $\overline{PAF}_s$ is:

$$16.34 \leq \mu \leq 30.23$$

Figure 3 illustrates the distributions of price adjustment factors for both change orders and supplemental agreements.

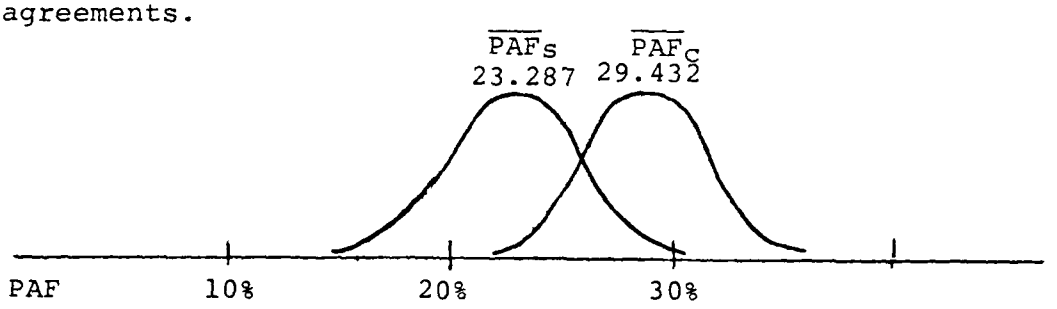


Fig. 3. Distributions of Price Adjustment Factors

It is clear from Figure 3 that the mean price adjustment factor for change orders is greater than the mean price adments factor for supplemental agreements. Since the price adjustment factor represents the decrease in the price of the effort, the larger price adjustment factor represents

the least costly alternative. The overlap between the two distributions indicates that it is possible for a random PAF_S to be greater than a random PAF_C. In this situation, the supplemental agreement would be less costly than a change order; however, Figure 3 indicates this will happen only occasionally.

A hypothesis test was performed to determine if the mean price adjustment factor for change orders was greater than for supplemental agreements at the .05 level of significance. This test indicated that it was not statistically greater at the .05 level of significance (Appendix D "Hypothesis Tests" Test 1). The test was performed again at the .25 level of significance. This second test indicated that the $\overline{PAF}_C$ is statistically greater than $\overline{PAF}_S$ (Appendix D "Hypothesis Tests" Test 2).

The raw data used to compute $\overline{PAF}_C$ and $\overline{PAF}_S$ are presented in Appendix E "Price Adjustment - Change Orders," and Appendix F "Price Adjustment - Supplemental Agreements" respectively.

Research Question 2

How does the time required to incorporate a change order compare to the time required to incorporate a supplemental agreement in those instances where the program office has received an unpriced proposal and can select either method of contractual incorporation?

The time required to incorporate a modification is the number of days between the date the program office receives the ECP and the date the contractor is given authorization to proceed. For change orders, this time generally includes the time it takes the program office to review the ECP, make any necessary revisions, and issue the contract modification document. For supplemental agreements this time includes the time it takes the contractor to fully price the proposal and negotiate a settlement in addition to the initial review and revision process which takes place. Consequently, the supplemental agreement logically should be the slower of the two alternatives. The findings of this study confirm this assertion.

The mean processing time for change orders ($\bar{T}_c$) was 43.05 days. The 95% confidence interval was:

$$27.88 \leqslant \mu \leqslant 58.21$$

The mean processing time for supplemental agreements was 186.11 days with a 95% confidence interval as follows:

$$114.5 \leqslant \mu \leqslant 257.72$$

Figure 4 illustrates the distributions of processing time for both the change order and the supplemental agreements.

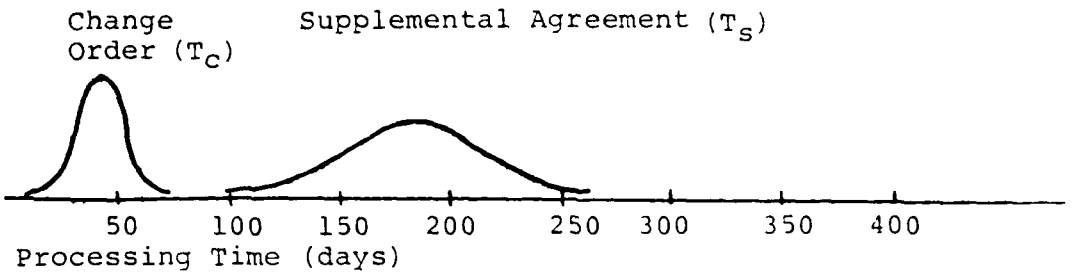


Fig. 4. Distributions of Processing Times

Clearly, the change order is the more expedient method. A hypothesis test for the difference of means confirmed that $\overline{T}_C$ is less than $\overline{T}_S$ at the .05 level of significance (Appendix D "Hypothesis Tests" Test 3).

The raw data used to compute $\overline{T}_C$ and $\overline{T}_S$ are presented in Appendix G "Processing Time - Change Orders," and Appendix H "Processing Time - Supplemental Agreements," respectively.

Additional Analysis

The primary emphasis of Phase I has been to determine the nature of the change order and the supplemental agreement with respect to the price adjustment realized during definitization and processing time. This analysis can be taken one step further by determining if there is a correlation between the price adjustment factor obtained for any given ECP and the time required to process that ECP.

Three regressions were performed as indicated in Table 1 "Regression - PAF vs Processing Time."

TABLE 1

REGRESSION - PAF with PROCESSING TIME

Regression	Dependent Variable	Independent Variable	Sample Points	Pearson Correlation Coefficient (r)
1	Price Adjustment Factor	Processing Time	All (1-37)	.0082
2	PAF_c	T_c	Change Orders (1-28)	.0907
3	PAF_s	T_s	Supplemental Agreements (29-37)	.6426

The correlation coefficients generated for each regression were tested for statistical significance, $\alpha = .05$ (Appendix D "Hypothesis Tests, Tests 4, 5, & 6").

The hypothesis tests generated the following conclusions. For all sample points, and for change orders only, the null hypotheses could not be rejected at the .05 level of significance. However, the tests performed for regression 3 indicate that there is a positive correlation between the price adjustment factor and the processing time for supplemental agreements.

Remember that the processing time for change orders does not include the time required to definitize the effort

because the contractor is given authorization to proceed before the effort is definitized. Therefore one would not expect the price adjustment factor to be correlated with the processing time. On the other hand, the processing time for supplemental agreements does include the time required to definitize the effort. Consequently, it is reasonable to assume the price adjustment factor would be correlated to the time required to process the ECP. The hypothesis tests confirm these assumptions. Furthermore, the positive correlation between the price adjustment factor and the processing time for supplemental agreements suggests that the government obtains a more favorable settlement in those cases where the definitization takes longer.

Phase II

Case Analysis

A common method of testing the validity of a model is case analysis. In case analysis the model is applied to actual situations. Then the model's estimates are compared to the actual results to determine if the model validly predicts what actually happens. Two cases have been selected to test the model developed in this study.

The first case is engineering change proposal F2780 titled "Eliminate Chafing of Hydraulic Hoses and Electrical Wire in the Wings and Nacelles." This change was precipitated when an accident investigation

> revealed that [an] inflight fire resulted from the chafing of a left wing slat hydraulic hose against an adjacent electrical harness, which resulted in shorting of the wire and localized failure of the hose [1:1].

Fairchild Republic Company proposed a fix which involved wrapping teflon spiral wrap chafe sleeves at the affected areas and replacing existing hoses with hoses which incorporate a teflon tubular chafe sleeve.

The second case is engineering change proposal F2768 R1 titled "Elimination of Water Intrusion Problems." This change was proposed in response to reports of ground aborts and electrical/avionic equipment problems resulting from water intrusion. The urgency of the change was tied to the scheduled NATO deployment of A-10A aircraft. The ECP proposed to install shields, grommets, and sealant where appropriate.

The methodology described in Chapter II was applied to the data listed in Appendix I - "Case Analysis Data," and generated the following results. For Case I the model estimated that the definitized price of the effort would be $189,404 if incorporated by change order, and $210,028 if incorporated by supplemental agreement. The actual definitized price of the supplemental agreement which incorporated this ECP was $173,334. In this case the model overestimated the price of the supplemental agreement by over $36,000.

The analysis for Case II generates similar results. For Case II the estimated definitized price of a change

order was $346,842. The estimated price of a supplemental agreement was $382,232. Again, the program office selected the supplemental agreement. The actual definitized price (adjusted to estimate the price of alternative II and III only) was $351,174. As before, the model overestimated the definitized price of the supplemental agreement, this time by over $31,000.

The results of these two analyses suggest that the model overestimates the price of the supplemental agreement. This is not necessarily the case however. On the contrary, the model underestimated the price to incorporate an ECP by supplemental agreement in five of the eight cases used in this study. This discrepancy reveals a major flaw with validation by case analysis. Case analysis often forces the analyst to draw conclusions on too limited a sample. A second method which can be used to test the validity of this model is correlation analysis. Correlation analysis accounts for all of the cases in the sample, thereby overcoming the primary deficiency of case analysis.

Correlation Analysis

Correlation analysis can be used to see if the model is making accurate predictions by determining if there is a significant correlation between the actual results and the estimated results. The model was applied to all 37 sample points to generate the estimate which corresponds to the decision of the program office. For example, if the program

office incorporated the effort by change order, the estimated price of a change order (C_{CO}) was calculated. The actual prices were extracted from the contract modifications. Appendix J "Correlation Analysis" contains the data used for this correlation analysis. Pearson correlation coefficients (r) were generated for three sets of sample points: all contract modifications, change orders only, and supplemental agreements only. The Pearson correlation coefficients for these three sets of sample points were .9986, .9986, and .9812 respectively. Hypothesis tests for the significance of correlation were conducted as described by equation 6 in Chapter II (Appendix D - "Hypothesis Tests," test 7,8, and 9). These hypotheses indicate that in all three cases there is a positive correlation which is statistically significant at the $\alpha = .05$ level of significance. In fact, the correlation is even significant when $\alpha = .0005$ [3:A-49]. While the hypothesis tests indicate a very strong correlation between the estimated and actual results, this correlation cannot be attributed solely to the validity of the model.

It must be remembered that the actual and estimated values are both directly proportional to the original not-to-exceed prices quoted for each effort. Consequently, a part of the correlation is due to the manner in which the actual and estimated results were generated, and not the validity of the model.

Algebraic Analysis

The validity of the model can also be tested algebraically. Essentially, the model reduces to the following:

$$P_s \times .70568 = C_{co} \qquad (16)$$

and

$$(P_s \pm \text{adjustment for delay}) \times .76613 = C_{sa} \qquad (17)$$

where .70568 and .76613 are equal to one minus the price adjustment factors generated in Phase I of this study. The break even point is that point at which the price of a change order (C_{co}) is equal to the price of a supplemental agreement (C_{sa}). This can be determined by setting the equation for C_{co} equal to the equation for C_{sa} or:

$$.70568(P_s) = .76613(P_s) + (C_r - C_p) \qquad (18)$$

where:

P_s = not-to-exceed price

C_r = price increase due to increased retrofit effort

C_p = price decrease due to decreased production effort

simplifying:

$$C_p - C_r = (.76613 - .70568)(P_s) \qquad (19)$$

$$C_p = .06045\ P_s + C_r \qquad (20)$$

The model was designed to balance the loss of cost control associated with the change order, with the more costly retrofit effort associated with the supplemental agreement. This balance would have been achieved if the mean price adjustment factor for supplemental agreements, exceeded the mean price adjustment factor for change orders. It did not, consequently, the model will almost always recommend the use of the change order. Equation 20 confirms this assertion. Remember that the cost of retrofit is generally more expensive than the cost of making the change in production [11:1]. Equation 20 indicates that the break even point occurs when C_p is greater than C_r. Since C_r is generally greater than C_p [11:1] the model will almost always recommend the use of the change order.

This conclusion does not necessarily indicate that the model is invalid. Rather it suggests that either:

1. the model has underestimated the price adjustment factor for supplemental agreements, and unduly favors the change order, or
2. the assumption that a loss of cost control makes the change order more expensive is overstated.

Sensitivity Analysis

Chapter II describes several variables which are used as inputs to the model. Most of the values for these

variables are extracted directly from the ECP. However, four variables must be estimated by the program manager. These variables are:

1. The price adjustment factor for change orders,
2. The price adjustment factor for supplemental agreements,
3. The processing time for change orders, and
4. The processing time for supplemental agreements.

Thus far, the analysis has used the values of $\overline{PAF}_C$, $\overline{PAF}_S$, $\overline{T}_C$, and $\overline{T}_S$ generated in Phase I as estimates for the four variables described above. Sensitivity analysis provides the opportunity to refine the model by using regression to improve these estimates.

First, regression analysis was applied to determine if there was a linear relationship between the price adjustment factors and the initial not-to-exceed price submitted with the ECP. If there was a relationship, the estimates for the price adjustment factors could be made sensitive to the initial not-to-exceed price. Three regressions were performed as indicated in Table 2 "Regression - PAF with P_S." Each Pearson correlation coefficient generated was tested for statistical significance in Appendix D "Hypothesis Tests," Tests 10-12. In all three cases, the relationship between the price adjustment factor and the not-to-exceed price was <u>not</u> statistically

TABLE 2

REGRESSION - PAF WITH P_s

REGRESSION	DEPENDENT VARIABLE	INDEPENDENT VARIABLE	SAMPLE POINTS	PEARSON CORRELATION COEFFICIENT
1	PAF_c, PAF_s	P_s	all	.0349
2	PAF_c	P_s	Change Orders	.0731
3	PAF_s	P_s	Supplemental Agreements	.4997

significant at the .05 level of significance. Consequently a variable price adjustment factor would not improve the model.

Sensitivity analysis was also applied to improve the estimated time delay ($\bar{T}_s - \bar{T}_c$). Regression analysis was used to investigate the existence of a linear relationship between processing time and the not-to-exceed price (P_s) as indicated in Table 3 "Regression - T with P_s." The hypothesis test for the statistical significance of the Pearson correlation coefficient for regression 1 indicated that there was not a statistically significant correlation between processing time and the initial not-to-exceed price for all sample points (ref: Appendix D: Hypothesis Tests" test 13).

However, the hypothesis tests conducted for regres-

TABLE 3

REGRESSION - T WITH P_s

REGRESSION	DEPENDENT VARIABLE	INDEPENDENT VARIABLE	SAMPLE POINTS	PEARSON CORRELATION COEFFICIENT
1	T_c, T_s	P_s	all	.0630
2	T_c	P_s	Change Orders	.4776
3	T_s	P_s	Supplemental Agreements	.7537

sions 2 and 3 indicated that there was a statistically significant linear relationship for both change orders and supplemental agreements (ref: Appendix D "Hypothesis Tests", test 14 and 15). The regression performed indicates that for change orders:

$$y = .0000062\,(x) + 34.3226$$

$$\text{processing time } (T_c) = .0000062\,(\text{initial price}) + 34.3226 \text{ days}$$

and for supplemental agreements:

$$y = .0003004\,(x) + 118.155$$

$$\text{processing time } (T_s) = .0003004\,(\text{initial price}) + 118.155 \text{ days}$$

These functions can be used to refine the model. The delay can be expressed as the difference between the

processing time for each alternative, or:

$$\text{delay} = (.0003004x + 118.155) - (.0000062x + 34.3446) \quad (21)$$

Since x represents the same initial price in both expressions, this equation simplifies to the following:

$$\text{delay} = .0002942x + 83.83 \quad (22)$$

Previously, the delay was calculated to be 143 days in all cases. Now the delay will be calculated per equation 22. For instance, if an ECP had a not-to-exceed price of $560,000, the model would now predict a delay of 248 days.

Correlation analysis was performed to determine if the refinement was in fact an improvement. The estimated price for each supplemental agreement was recalculated using this delay refinement. The revised estimates were then regressed with the actual results. This regression generated a Pearson correlation coefficient (r) of .9928. The correlation between the estimated and actual price of supplemental agreements prior to the refinement was .9812. Since the new correlation coefficient was higher, the model was revised to include the "delay refinement." Step 3 of the model is changed to the following:

Step 3: Compute the estimated time delay ($\bar{T}_D$).

$$\bar{T}_D = .0002942(P_s) + 83.83$$

Application

This model can be applied to another program. The relationships built into the model are well substantiated in the literature as well as actual practice. The success of the model depends on how accurately the using program office estimates:

1. the price adjustment factor for change orders (PAF_c)
2. the price adjustment factor for supplemental agreements (PAF_s)
3. the time delay associated with the supplemental agreement ($\bar{T}_D$).

In this study the price adjustment factor for change orders (PAF_c) was estimated by taking a sample of 28 change orders executed during a single year and calculating a mean ($\overline{PAF}_c$).

The 95% confidence interval was relatively tight, ranging from approximately 23% to 36% so the estimate of 29.432% is a fairly reliable estimate for this study. This rate should not however, be used by a different program office because this rate is a function of several factors which are specific to the program used in this study. There are several factors which the program manager should consider when formulating an estimate of the price adjustment factor for change orders.

1. What is the risk factor applied by the contractor

when submitting a not-to-exceed price? Some contractors will add a risk factor of 20% while others may double their estimates of what the ECP should cost. The risk factor applied by the contractor can be obtained through conversations with the contractor's pricing staff. Oftentimes it is provided in the ECP. The program office contracting staff will also have a good idea of how large a risk factor is applied.

2. What phase of the acquisition process is the program in? Contractors will generally apply a larger risk factor early in the development phase when the system design is still evolving. Once the program office begins production however, the risk factor stabilizes. This assertion was confirmed through an analysis of variance (ANOVA). The ANOVA was applied to determine if price adjustment factors calculated early in the production phase could be used to predict price adjustment factors later in production. The data for this study were divided into 8 time treatment groups. The ANOVA indicated the price adjustment factors did not change as the system progressed to the later stages of the production effort.

3. What is the nature of the environment in the using programs contracts office? If the office is overworked and unable to provide sufficient support to rigorous fact-finding, or if the pressure to definitize efforts quickly is undermining the negotiators' leverage, a contract

office may not be realizing an optimal price adjustment.

These three factors can be used to formulate a theoretical estimate of the price adjustment factor for change orders. This theoretical estimate can be formulated at any point in the acquisition process. A program office may prefer to calculate an estimate based on a sample mean as in this study. Bearing in mind the factors described above, a mean can be calculated based on any sample size. A program manager should be able to increase his or her confidence in the estimate by increasing the sample size. A sample size of 30 is typically associated with the minimum number of sample points required to assume that a distribution is normal.

This study estimated the price adjustment factor for supplemental agreements (PAF_S) in the same manner that PAF_C was estimated. A sample of 8 supplemental agreements executed during 1981 was used to calculate a mean and 95% confidence interval. The small sample size did impact the width of the confidence interval. As before, the 23.387% value of $\overline{PAF}_S$ should not be used by another program office. A theoretical PAF_S can be formulated by considering the following factor in addition to the three factors discussed for change orders.

1. What is the nature of the system? Aircraft systems typically involve retrofit, which increases the cost

of the supplemental agreement. Different types of systems may not require retrofit.

An estimate can also be obtained statistically using the procedures employed in Phase I of this study. A larger sample size will increase the confidence associated with an estimate.

The third parameter which m st be estimated is the time delay associated with the supplemental agreement. This study estimated this delay be computing the difference between the mean processing time for change orders ($\bar{T}_c$) and the mean processing time for supplemental agreements ($\bar{T}_s$). This study then refined this estimate by regressing processing time with the initial not-to-exceed price. Another program office can employ either of these techniques. Again, a larger sample size will improve the confidence associated with these estimates. A theoretical estimate can also be formulated, and should consider the following factors:

1. What activities contribute to the delay? How long do these activities take? If an ECP is deferred to allow incorporation by supplemental agreement, the ECP must be fully priced, then the ECP must be reviewed again. Once the change is approved it must be negotiated. The contractor is responsible for pricing the ECP and is probably the best source for estimating other time required to complete that activity. The program manager is best qualified to estimate

how long the program office will review the ECP before approving it. Finally, the contracts office is a good source to estimate the time required to negotiate the effort.

2. *How complex is the task?* A simple task is more easily priced, reviewed, and negotiated than a complex task.

3. How expensive is the ECP? The review cycle, and the negotiation cycle become more rigorous as the cost of an ECP increases above certain legal thresholds.

4. How does the contractor view incorporation of the effort? It is possible that a contractor is not in favor of the proposed modification. This may occur in cases where the contractor feels that changes that result from changes made by an associate contractor or made in government furnished equipment may adversely impact the system. If the contractor is not in favor of incorporating a proposed modification there is a good chance it will take longer.

5. How well staffed is the contracting office? If the office is understaffed the contract modifications requiring definitization may have to wait to be negotiated.

This section has described how another program office should use the model developed in this study. The section has emphasized that the success of the model is heavily dependent on the accuracy of the estimates for PAF_c, PAF_s and $\bar{T}_D$. Several factors have been listed to assist program managers in developing accurate estimates for those parameters.

Summary

Several objectives were accomplished in Phase I. First, the mean price adjustment factors for change orders and supplemental agreements were calculated and compared. Second, the mean processing times for change orders and supplemental agreements were calculated and compared. Third, correlation analysis determined that there was a correlation between processing time and the price adjustment factor for supplemental agreements. In Phase II, the model was tested for validity using case analysis, correlation analysis, and algebraic analysis. Sensitivity analysis was then applied to refine the model. This sensitivity analysis determined that there was a significant correlation between the initial ceiling price and the processing time for both change orders and supplemental agreements. These relationships were then used to refine the model. Finally, the application of the model was discussed. Emphasis was placed on the importance of the estimates for PAF_C, PAF_S and T_D. Several factors were discussed to assist the program manager make these estimates.

CHAPTER IV

CONCLUSION

Summary

The two objectives of this study were to first, quantitatively compare the cost and schedule impact of the change order and the supplemental agreement, and second, to test a model to assist program managers in determining whether an ECP should be incorporated by a change order or a supplemental agreement.

Phase I of this study determined that the program office could expect to decrease the not-to-exceed price submitted with an ECP by a larger amount if the effort was incorporated by change order. In the case of the change order, the not-to-exceed price was decreased by an average of 29% by the time the effort was finally definitized. The mean decrease in the price experienced in those cases where the program office chose to incorporate the ECP by supplemental agreement was 23%. The difference in mean price adjustment factors, however, was not statistically significant ($\alpha = .05$).

Phase I also investigated the schedule impact of delaying incorporation of an urgent ECP until the contractor could provide a fully priced proposal. This study indicates that when an ECP is incorporated by change order it takes

the program office an average of 43 days from receipt of the proposal until the contractor is authorized to proceed. This time is for reviewing the ECP, planning its implementation, and modifying the ECP if necessary.

For the supplemental agreement, the average time required to "turn on" the contractor from the time the program office received the ECP was 186 days. The primary difference in time is attributed to the time the contractor spends preparing the fully priced proposal and the time that both the government and contractor spend negotiating an equitable adjustment. This study concludes that the change order is the more expedient of the two alternatives. These findings are consistent with those reported in the literature [4:110].

The second objective of this study was to test a model to assist program managers in determining whether an ECP should be incorporated by change order or by supplemental agreement. Three methods were used to test the validity of the model: case analysis, correlation analysis, and algebraic analysis. The results of all three methods were inconclusive. First, the conclusions generated by case analysis are based on too small a sample. Second, while the correlation analysis indicated a very strong correlation between actual and predicted results, there was no way to distinguish between how much of the correlation was due to the validity of the model, and how much was due to the fact that both the

actual and predicted results are directly proportional to the not-to-exceed price. Finally, algebraic analysis was inconclusive because there was no way to determine if the model's preference for change orders was invalid, or if the assumed loss of cost control associated with change orders was overstated.

The fact that the tests conducted in Phase II of this study were inconclusive does not rule out the use of the model by other programs. Ultimately, the validity of the model is dependent upon the accuracy of the estimated price adjustment factors for change orders and supplemental agreements as well as the estimated time delay. A program which can formulate accurate estimates for these parameters, can use this model very successfully. Finally, it should be noted that the model should only be applied in those instances where cost is driving the decision between the two alternatives. When there are safety factors involved the urgency of the problem may require the use of a change order regardless of the cost impact.

The major limitation of this study stems from the framework employed to compare the change order to the supplemental agreement. Change orders result from ECPs submitted with only an NTE price. Supplemental agreements usually incorporate ECPs submitted with a firm quote. The only way to insure a valid comparison was to limit the study to supplemental agreements which incorporated ECPs originally

submitted with a NTE price. Supplemental agreements which incorporated ECPs which were originally submitted with a firm price were excluded from this study. It is probable that over the life of the system, the use of the supplemental agreement is less expensive. The recommendations for further study will include a recommendation to test this hypothesis.

Despite this limitation, it is clear that at least in the case of the A-10A program, when a contractor submitted an urgent ECP with a not-to-exceed price, the change order proved to be the least costly instrument to incorporate the ECP into the existing contracts ($\alpha = .25$). Efforts which were delayed to allow for incorporation by supplemental agreement in accordance with current procurement policy ultimately resulted in a greater expense to the government. Furthermore, the change order was considerably more expedient than the supplemental agreement. Since other programs may face similar acquisition environments, this study suggests that change order policy be administered on a system-by-system basis. This study can draw no conclusions concerning efforts which were slated for incorporation by supplemental agreement from their inception.

Recommended Further Study

1. This study did not assess the cost impact of supplemental agreements which were originally submitted as

a fully priced proposal. A study should be performed which would investigate contracts which have already been terminated and determine what percentage of the contract modifications were change orders and what percentage of the contract modifications were supplemental agreements. The study would then determine the cost growth which was experienced over the life of the contract. If this information was taken for a number of contracts the study could determine if the cost growth per contract was a function of the type of contract modifications which were issued. The study should hypothesize that the contracts with the highest percentage of supplemental agreements would evidence the least cost growth.

2. This study suggested that the change order could be a very useful tool even in an ordinary situation. One of the factors affecting the use of the change order is the "timeline" management system which is imposed when an effort is incorporated by change order. Essentially, this system requires that a change order be definitized within 180 days from the date the modification is approved and issued. The timely definitization of change orders is scrutinized at all levels within the procurement system and in fact the pressure to definitize the change order quickly can adversely impact a negotiator's leverage. A study should be performed which would analyze "time-line" management procedures currently in effect with a special emphasis on incor-

porating procedures which would allow the negotiator to exceed the 180 day limit in cases where the negotiator feels the time limit is adversely impacting his leverage. The waivers could be controlled to prevent the level of undefinitized work from getting out of control. Additionally, the very existence of these "waiver" procedures would prevent the contractor from ever assuming the negotiator is running out of time, and consequently, the procedures would help even in cases where the waivers were not granted.

3. This study was performed on the A-10A weapon system. This system is an aircraft system which consists of both production and retrofit units. The system is produced by the Fairchild Republic Company. The data used for this analysis was taken from the very late stages of production. This study should be repeated for programs which alter any of the variables described above. The study should repeat both Phase I and Phase II for these additional systems. The results of the additional studies should then be compared and integrated with the results of this study. If the studies conducted on additional systems generated similar results, there would be a strong argument to deemphasize the pressure exerted against the use of the change order.

APPENDICES

APPENDIX A

SAMPLE POINTS

ECP	CONTRACT	MOD #	MOD #
F0270-5 R1	F33657-78-C-0135	P00232 (C.O.)	P00246 (S/A)
F0465 & -1	F33657-79-C-0502	P00035 (S/A)	
F0477R1 & -1R1	-0135	P00209 (S/A)	
F0477R1	-0502	P00058 (S/A)	
F0524 R1	-0135	P00163 (C.O.)	P00207 (S/A)
F0548P	-0502		P00060 (S/A)
F0550, R2	-0135	P00166 (Long Lead)	
		P00199 (C.O.)	P00228 (S/A)
F0570 & -1	-0502	P00052 (S/A)	
F0604	-0135	P00181 (C.O.)	P00221 (S/A)
F0604	-0502	P00033 (C.O.)	P00057 (S/A)
F0610P	-0135	P00217 (C.O.)	P000268 (S/A)
F0610P	-0502	P00065 (C.O.)	P00110 (S/A)
F0621	-0502	P00074 (C.O.)	P00114 (S/A)
F0905	-0502	P00048 (C.O.)	P00085 (S/A)
F0908P	-0135	P00184 (C.O.)	P00216 (S/A)
F0908	-0502	P00053 (S/A)	
F0910P	-0135	P00213 (C.O.)	P00268 (S/A)
F0910P	-0502	P00062 (C.O.)	P00110 (S/A)
F2206R3-1R3	-0135	P00209 (S/A)	
F2206R3	-0502	P00058 (S/A)	
F2768R1	-0135	P00222 (S/A)	
F2768R1	-0502	P00069 (S/A)	
F2780 & R1	-0135	P00194 (S/A)	
F2780 & R1	-0502	P00042 (S/A)	
F2798	-0135	P00233 (C.O.)	P00265 (S/A)
F2798	-0502	P00075 (C.O.)	P00109 (S/A)
F3055R4	-0135	P00234 (S/A)	
F3151R1	-0135	P00176 (C.O.)	P00209 (S/A)
F3151R1	-0502	P00026 (C.O.)	P00058 (S/A)
F3156R1	-0135	P00194 (S/A)	
F3156R1	-0502	P00042 (S/A)	
F3159 R2	-0502	P00027 (C.O.)	P00071 (S/A)
F3194	-0135	P00256 (S/A)	
F3195	-0135	P00163 (C.O.)	P00207 (S/A)
F3195	-0502	P00015 (C.O.)	P00059 (S/A)
F3235	-0135	P00139 (C.O.)	P00192 (S/A)
F3235R1P	-0135	P00217 (C.O.)	P00268 (S/A)
F3235R1	-0502	P00165 (C.O.)	P00110 (S/A)
F3246 R1 & 1R1	-0502	P00110 (S/A)	
F3251	-0502	P00063 (S/A)	
F3253	-0135	P00203 (S/A)	
F3255	-0135	P00148 (C.O.)	P00192 (S/A)

ECP	CONTRACT	MOD #	MOD #
F3272	-0135	P00169 (Long Lead)	
		P00196 (C.O.)	P00236 (S/A)
F3272	-0502	P00044 (C.O.)	P00085 (S/A)
F3280	-0502	P00085 (S/A)	
F3324R2P	-0135	P00248 (C.O.)	P00290 (S/A)
F3324R2	-0502	P00091 (C.O.)	L00126 (S/A)
F3325R2P	-0135	P00253 (C.O.)	P00271 (S/A)
F3325P	-0502	P00123 (C.O.)	
F3336P	-0135	P00273 (C.O.)	P00305 (S/A)
F3336P	-0502	P00118 (C.O.)	P00170 (S/A)

APPENDIX B

CHANGE ORDERS

INDEX	ECP	CONTRACT
01	F0270-5R1	-0135
02	F0524 R1	-0135
03	F055J, R2	-0135
04	F0604	-0135
05	F0604	-0502
06	F9610P	-0135
07	F0610P	-0502
08	F0621	-0502
09	F0905	-0502
10	F0908P	-0135
11	F0910P	-0135
12	F0910P	-0502
13	F2798	-0135
14	F2798	-0502
15	F3151R1	-0135
16	F3151R1	-0502
17	F3159R2	-0502
18	F3195	-0135
19	F3195	-0502
20	F3235	-0135
21	F3235R1P	-0135
22	F3235R1	-0502
23	F3272	-0135
24	F3272	-0502
25	F3324R2P	-0135
26	F3324R2	-0502
27	F3336P	-0135
28	F3336P	-0502

*Four change orders were deleted from the original list of 51 for the following reasons:

1. F0548 - the cost information for the initial change order was unavailable.

2. F3255 - the recommended fix was redefined after the issuance of the initial change order, consequently the definitized price does not address the same level of effort as the initial not-to-exceed price.

3. F3325R2P and F3325P - these efforts were terminated prior to completion.

APPENDIX C

SUPPLEMENTAL AGREEMENTS

INDEX	ECP	CONTRACT #
29	F0477R1-1R1	-0135
	F0477R1	-0502
30	F0908	-0502
31	F2206R3 & 1R3	-0135
	F2206 R3	-0502
32	F2768R1	-0135
	F2768R1	-0502
33	F2780 & R1	-0135
	F2780 & R1	-0502
34	F3055R4	-0135
35	F3156R1	-0135
	F3156R1	-0502
36	F3251	-0502
37	F3253	-0135

APPENDIX D

HYPOTHESIS TESTS

TEST #	(H_o) HYPOTHESIS	(H_a) ALTERNATE HYPOTHESIS	CRITICAL VALUE (α = .05)	TEST STATISTIC	CONCLUSION
1	$PAF_s - PAF_c \geq 0$	$PAF_s - PAF_c < 0$	-1.690	-1.0030	cannot reject H_o
2	$PAF_s - PAF_c \geq 0$	$PAF_s - PAF_c < 0$	-.682*	-1.0030	reject H_o
3	$T_s - T_c \leq 0$	$T_s - T_c > 0$	1.703	6.1000	reject H_o
4	$p = 0$	$p > 0$	1.690	.0478	cannot reject H_o
5	$p = 0$	$p > 0$	1.706	.4640	cannot reject H_o
6	$p = 0$	$p > 0$	1.943	2.0540	reject H_o
7	$p = 0$	$p > 0$	1.690	110.0700	reject H_o
8	$p = 0$	$p > 0$	1.706	96.2600	reject H_o
9	$p = 0$	$p > 0$	1.943	12.4500	reject H_o
10	$p = 0$	$p > 0$	1.690	.2000	cannot reject H_o
11	$p = 0$	$p > 0$	1.706	.3700	cannot reject H_o
12	$p = 0$	$p > 0$	1.943	1.4100	cannot reject H_o
13	$p = 0$	$p > 0$	1.690	.3680	cannot reject H_o
14	$p = 0$	$p > 0$	1.706	2.7700	reject H_o
15	$p = 0$	$p \quad 0$	1.943	2.8000	reject H_o

Note: * α = .25

APPENDIX E

PRICE ADJUSTMENT - CHANGE ORDERS

INDEX	P_s (NOT-TO-EXCEED PRICE)	P_f (DEFINITIZED PRICE)	PAF_c
01	4,256,065	3,325,000	21.0
02	560,000	354,000	36.7
03	11,794,900	8,847,943	25.0
04	793,000	780,305	1.6
05	70,000	44,928	35.8
06	593,300	371,627	37.4
07	426,800	33,824	21.8
08	164,400	106,117	35.5
09	246,900	164,790	33.3
10	126,800	120,384	5.1
11	103,600	60,341	41.8
12	213,100	151,577	28.9
13	26,700	26,700	0.0
14	21,300	16,559	22.3
15	170,600	64,817	62.0
16	195,500	185,452	5.1
17	1,991,500	1,201,700	39.7
18	832,900	658,500	20.9
19	458,000	436,500	4.7
20	1,543,100	1,069,014	30.7
21	585,200	389,923	33.4
22	593,600	440,804	25.7
23	606,700	395,759	34.8
24	327,800	103,597	68.4
25	253,000	164,713	34.9
26	185,900	114,786	38.2
27	132,240	97,385	26.4
28	134,900	64,627	52.1

$$\overline{PAF}_c = 29.432\%$$

95% C.I. = $23.01 \leq \mu \leq 35.85$

APPENDIX F

PRICE ADJUSTMENT - SUPPLEMENTAL AGREEMENTS

INDEX	P_s NOT-TO-EXCEED PRICE	P_f (DEFINITIZED PRICE)	PAF_s
29	138,300	93,714	32.3
30	39,000	34,656	11.1
32	666,833	476,492	28.5
33	268,400	173,334	35.4
34	21,600	18,641	13.7
35	168,700	135,574	19.6
36	32,817	24,951	24.0
37	38,200	29,571	22.6

$$\overline{PAF_s} = 23.287\%$$

95% C.I. = $16.34 \leq \mu \leq 30.23$

APPENDIX G

PROCESSING TIME - CHANGE ORDERS

INDEX #	T_b DATE ECP REC'D	SEQ VALUE	T_f EFFECTIVE DATE OF MOD	SEQ VALUE	T_c PROCESS TIME
01	2 Apr 81	489	19 Jun 81	567	78
02	22 Jul 80	235	15 Oct 80	320	85
03	12 Nov 80	348	20 Feb 81	448	100
04	17 Nov 80	353	3 Dec 80	369	16
05	17 Nov 80	353	3 Dec 80	369	16*
06	18 Mar 81	473	11 May 81	528	55
07	18 Mar 81	473	11 May 81	528	55*
08	21 May 81	538	12 Jun 81	560	22
09	29 Dec 80	395	5 Mar 81	461	66
10	1 Dec 80	367	23 Dec 80	389	22
11	14 Apr 81	501	27 Apr 81	514	13
12	14 Apr 81	501	27 Apr 81	514	13*
13	17 Jun 81	565	19 Jun 81	567	02
14	17 Jun 81	565	19 Jun 81	567	02*
15	15 Oct 80	320	17 Nov 80	353	33
16	15 Oct 80	320	18 Nov 80	354	34*
17	1 Oct 80	306	17 Nov 80	353	47
18	18 Aug 80	262	15 Oct 80	320	58
19	18 Aug 80	262	15 Oct 80	320	58*
20	27 Jun 80	210	3 Jul 80	216	06
21	7 May 81	524	11 May 81	528	04
22	12 Aug 81	621	24 Nov 81	725	104
23	17 Dec 80	383	6 Feb 81	434	51
24	17 Dec 80	383	6 Feb 81	434	51*
25	20 Aug 81	629	21 Aug 81	630	01
26	9 Dec 81	740	4 Feb 82	797	57
27	3 Nov 81	704	14 Dec 81	745	41
28	3 Nov 81	704	14 Dec 81	745	41*

*Indicates points which were not included in the calculation of mean processing time. These sample points result from the same ECPs as the points immediately above them in the table.

$$T_c = 43.05 \text{ days}$$

$$95\% \text{ C.I.} = 27.88 \leq \mu \leq 58.21$$

APPENDIX H

PROCESSING TIME - SUPPLEMENTAL AGREEMENTS

INDEX #	T_b DATE ECP REC'D	SEQ VALUE	T_f EFFECTIVE DATE OF MOD	SEQ VALUE	T_c PROCESS TIME
29	7 Dec 79	07	23 Apr 80	145	138
30	1 Dec 80	367	6 Apr 81	493	126
31	10 Jun 80	193	23 Apr 81	510	317
32	20 Aug 80	264	22 Jun 81	570	306
33	25 Jun 80	208	17 Feb 81	445	237
34	22 Jun 81	570	30 Jun 81	578	08
35	4 Sep 80	279	17 Feb 81	445	166
36	31 Oct 80	336	8 May 81	525	189
37	17 Sep 80	292	24 Mar 81	480	188

$$\overline{T}_s = 186.11$$

95% C.I. = $114.50 \leq \mu \leq 257.72$

APPENDIX I

CASE ANALYSIS DATA

GIVEN	CASE I	CASE II
C_a	121,000	Alt II 58,000 Alt III 64,100
C_b	5900 (-0135), 16,100 (-0502)	Alt II 7,600 Alt III 2,800 (-0502), 2,500 (TBD)
N_r	450 (465 - 15 attrits)	Alt II 474 Alt III 566
N_f	489 (-0135), 633 (-0502)	489 (-0135), 633 (-0502), 692 (TBD)
N_p	466	Alt II 490 Alt III 582
P_s	268,400	Alt II 280,800 Alt III 210,700
N_s	24 (-0135), 144 (-0502)	Alt II 144 Alt III 52 (-0502), 60 (TBD)
R	12	12

	CASE I	CASE II
ESTIMATED PHASE I		
$\overline{PAF}_c$	.29432	.29432
$\overline{PAF}_s$	.23387	.23387
$\overline{T}_c$	43.05	43.05
$\overline{T}_s$	186.11	186.11
COMPUTED		
C_{co}	189,404.51	346,842
T_D	143	143
N_D	57	57
C_r	15,339.27	13,429.77
C_p	9,589.32	6,015.87
C_{sa}	210,028	383,323

Notes:

1. The 4 digit numbers in parenthesis identify contracts. Some of the items listed in the chart are different for each contract affected by the ECP. In these cases, both values used have been presented and identified with the appropriate contract (i.e., -0135. The symbol (TBD) indicates the contract number is yet to be determined.

2. Case II presents data which pertains to two alternatives. These alternatives were separately exercisable options which addressed the same problems. The difference lies in which part of the aircraft each alternative proposes to fix.

APPENDIX J

CORRELATION ANALYSIS

	*SAMPLE INDEX NUMBER	X_i ACTUAL PRICE	Y_i ESTIMATED PRICE	REVISED ESTIMATE
CHANGE ORDERS	01	3,325,000	3,003,420	
	02	354,000	395,180	
	03	8,947,943	8,323,425	
	04	780,305	559,604	
	05	44,928	49,398	
	06	371,627	418,680	
	07	333,824	310,390	
	08	106,117	116,104	
	09	164,790	174,232	
	10	120,384	92,215	
	11	60,341	75,343	
	12	151,577	150,380	
	13	26,700	19,417	
	14	16,559	15,490	
	15	64,817	120,389	
	16	185,452	142,177	
	17	1,201,700	1,448,318	
	18	658,500	605,727	
	19	436,500	323,201	
	20	1,069,014	1,122,219	
	21	389,923	425,587	
	22	440,804	431,696	
	23	395,759	441,223	
	24	103,597	231,322	
	25	164,713	183,994	
	26	114,786	131,186	
	27	97,385	93,319	
	28	64,627	98,106	
SUPPLEMENTAL AGREEMENTS	29	93,714	106,090	106,105
	30	34,056	29,879	29,879
	31	-	-	-
	32	351,174	382,232	387,138
	33	173,334	210,028	211,760
	34	18,641	16,548	16,548
	35	135,574	116,216	113,822
	36	24,951	24,709	24,753
	37	29,571	29,266	29,266

*These index numbers correspond to the index numbers in Appendix B and Appendix C

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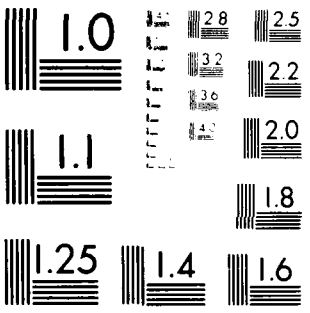

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